Beyond Retinal Screening: Digital Imaging in the Assessment and Follow-up of Patients with Diabetic Retinopathy

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Many screening methods are available for detecting diabetic retinopathy. However, once patients develop retinopathy, it is unclear as to what method should be used for their review. We describe a novel and integrated system for the screening and treatment of diabetic retinopathy using high street optometrists for primary screening and digital imaging as a secondary screening tool, with referral to a joint retinal clinic only where ophthalmological intervention may be required. Of 3586 patients screened by optometrists, 328 were classified as having moderate/severe pre-proliferative retinopathy or diabetic maculopathy. Patients with proliferative retinopathy (1 % of the total) were recalled directly to the joint retinal clinic. A consecutive sample (281) of these patients, together with a further 100 classified by the optometrists as having no or background retinopathy were compared using digital images and standard 35 mm colour transparencies. These, together with the original optometrist reports, were reviewed independently and individually by an opthalmologist. A further sample of 124 patients who had undergone both digital imaging and ophthalmologist slit-lamp examination were also compared. Comparison of 35 mm colour transparencies with optometrist reports showed the latter had a sensitivity for detecting sight-threatening retinopathy (STR) of 62 %, a specificity of 84 %, and a kappa score of 0.62. The results for digital images were 90 %, 97 %, and 0.90, respectively, although the extent of retinopathy was under-reported in 10 patients. With opthalmologist slit-lamp examination as the gold standard, the sensitivity of digital imaging was 90 % with a substantial level of agreement between them (kappa 0.61). We conclude that digital images provide an efficient method for the follow-up of patients with established or previously treated retinopathy. © 1998 John Wiley & Sons, Ltd.

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Introduction

Early treatment of diabetic retinopathy is undoubtedly effective in clinical and economic terms.[1,2] There are, however, a number of practical problems relating to follow-up and review of retinal appearances in such patients. Most diabetic patients are managed solely in primary care. In patients with established retinopathy, coexistent factors for progression of the disease need to be considered. Communication between primary care, diabetologists, and ophthalmologists is often poor. Without a co-ordinated approach between these care providers, it is likely that some patients will be managed inappropriately. There is a paucity of data relating to the effectiveness of the screening method as a tool for follow-up of patients with established and/or treated retinopathy. It is important to consider models of care which take the above into consideration, are locally acceptable and can, in turn, enhance patient acceptability by minimizing the number of hospital visits.

The aim of this study was to evaluate a novel and integrated system for the screening and treatment of diabetic retinopathy using high street optometrists for primary screening and digital imaging as a secondary screening tool, with referral to a joint retinal clinic only where ophthalmological intervention may be required.

Methods

In East Dorset, patients attend high street optometrists for retinal screening through dilated pupils, with recall organized on an annual basis.[3] Retinal appearances are described according to an agreed coding system, with the results recorded on a hospital-based diabetes register and a copy sent to the general practitioner. Information on glaucoma, non-diabetic maculopathy and cataracts is

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also available from the optometrist assessment. Thereafter, patients are classified according to predefined criteria into clinical assessment groups, each named BRAG for Bournemouth Retinopathy Assessment Group:

BRAG I = no retinopathy
BRAG II = background retinopathy
BRAG III = diabetes-related maculopathy
BRAG IV = minor pre-proliferative retinopathy
BRAG V = moderate/severe pre-proliferative retinopathy
BRAG VI = proliferative retinopathy

Patients in BRAG I and II are referred back to the optometrists for continued screening. Patients in BRAG VI are recalled directly to a hospital-based Joint Retinal Clinic (JRC). This weekly clinic is staffed by a consultant diabetologist and ophthalmologist where eye examination takes place by slit-lamp assessment through dilated pupils (1 % tropicamide). A portable laser is also available for immediate photocoagulation. Patients with diminished visual acuity related to cataract or individuals with glaucoma are recalled directly to the local eye hospital.

For patients with BRAG III–V, and for individuals who are no longer under active follow-up in the JRC, a novel system has been developed utilizing digital imaging technology. Within a specific 'Image Clinic', digital images are taken through dilated pupils (Topcon Imagenet 640, Topcon Corp., Tokyo), together with the assessment of visual acuity, HbA_{1c}, lipids, and blood pressure. Three 50° field images are taken of each eye, with the first image incorporating the optic disc and macula areas. The Image Clinic is staffed by a nurse, a medical photographer, and a retinal secretary. Within 1–2 weeks, all digital images are reviewed by a consultant ophthalmologist and diabetologist and a decision is made about treatment/follow-up. Information including recorded retinal images as well as clinical and biochemical data are sent to the general practitioner and a letter explaining the findings together with a treatment plan are also sent to individual patients (Figure 1). Thus, patients can move between the Image Clinic and Joint Retinal Clinic (as well as primary optometrist screening) according to clinical need.

The first Image Clinic was held on 2 May 1995. Between May 1995 and December 1996. The following assessments were available for patients recalled to the Image Clinic (n = 281):

1. Optometrist coded reports and subsequent conversion to BRAG's.
2. Ophthalmologist reviewed digital images. The 50° fields included disc and macula, and macula centred with upper and lower branches of the 'temporal triangle'. Extra nasal views were also taken.
3. Ophthalmologist reviewed 35 mm colour transparencies (three 50° fields) taken at the same time as the digital images by the same individual.

In addition, for the purposes of evaluating the programme, a random sample of 50 patients with no retinopathy (BRAG I by optometrist screening) and a similar number with background retinopathy (BRAG II) were recalled to the Image Clinic. Subsequently a random sample of 124 patients who had attended both the Image Clinic and Joint Retinal clinics in 1996–97 were compared with ophthalmologist slit-lamp examination used as a gold standard (see Table 3).

All images were coded and grouped by a consultant ophthalmologist without access to original optometrist codes. Digital and 35 mm images were coded separately and without access to the other.

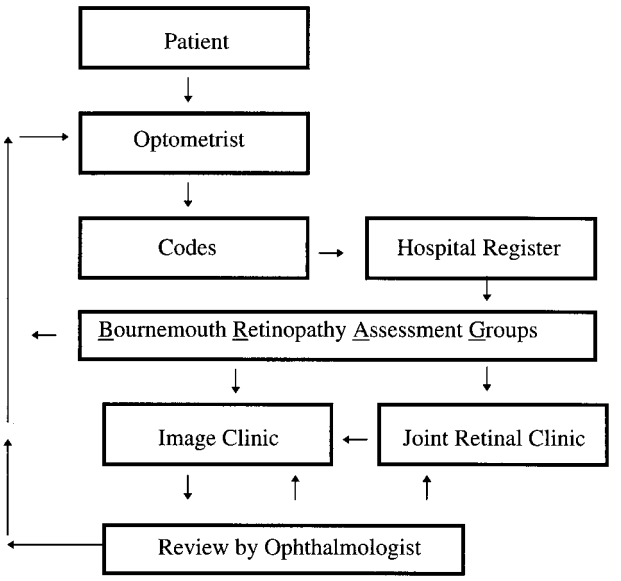

Figure 1. Digital imaging in the assessment, treatment and follow-up of patients with diabetic retinopathy

Statistical Analyses

For the purposes of comparison, the reference standard was ophthalmologist assessment of 35 mm colour transparencies taken through dilated pupils. The kappa statistic was used to relate the amount of agreement with that which might have been expected by chance. Complete agreement is expressed as a kappa score of 1.0 with a value of <0.8 as almost perfect, 0.61–0.8 as substantial, 0.41–0.6 as moderate, 0.21–0.4 as fair and <0.2 as poor.[4] Calculations were also made of sensitivity (probability of correct positive screening), specificity (probability of correct negative screening), positive and negative predictive values and yield (true positives as a proportion of total number tested.

Results

Between May 1995 and December 1996, primary screening optometrist codes were available on 3586 patients (Table 1). Seven hundred and ninety-four (22 %) had retinopathy, of whom 426 (12 %) were transferred back to the optometrist for subsequent screening (simple

Table 1. Prevalence of diabetic retinopathy within the Bournemouth diabetes database between 1/7/95 and 31/12/96

	n	%
Total number of patients screened	3586	100
Gender		
male	1965	55
female	1621	45
Age (yr)		
<40	290	8
41–64	1079	30
65–74	1065	29
>75	1098	31
Unknown	54	2
Visual acuity		
>660 both eyes		0.5
>660 either eye		3.0
Retinopathy group		
BRAG I	2826	78
BRAG II	426	12
BRAG III	171	5
BRAG IV	121	3
BRAG V	36	1
BRAG VI	40	1

background retinopathy). Of the remainder, 40 (1.1 % of the total) were recalled directly to the Joint Retinal Clinic (BRAG VI proliferative retinopathy) and the rest to the Image Clinic. Forty-six patients were excluded as their data set was incomplete, there was a delay of >4 months between the different examinations or they were unwilling to have all three examinations. Of the 100 patients who would, under normal circumstances, not be recalled (either no retinopathy or simple background, BRAG I–II), 6 were under-reported by optometrists, i.e. they had sight-threatening retinopathy, all pre-proliferative changes.

Of the patients recalled to the Image Clinic, 94 (32 %) were transferred back to the optometrists for subsequent screening, 76 (26 %) were given further Image Clinic appointments and the rest (42 %) were seen in the joint retinal clinic where 32 % were treated with laser on their first visit. The failure to attend rate for the Image Clinic was less than 1 %.

For the purposes of comparisons based on current clinical practice, patients were divided into those without (BRAG I/II) and those with (BRAG III–VI) sight-threatening retinopathy (Table 2). There was substantial agreement between optometrist codes and standard 35 mm transparencies (kappa 0.62) and between digital and 35 mm images (kappa 0.90). In 10 patients, digital images under-reported the presence of retinopathy (Table 3). For patients who had both digital images and ophthalmologist slit-lamp examination, the sensitivity of the former for detecting STR was 90 % with a substantial level of agreement (kappa 0.61) (Table 4).

Discussion

In Bournemouth, high street optometrists provide the facility for primary screening for retinopathy, with the retinal appearances recorded using a standard coding sysem.[3] This procedure has modest set-up and low administration costs. Although patients are responsible for arranging their own optometrist appointment, following their first eye screen they are sent an annual reminder. The coded formats are quick and easy to interpret and have been designed for computer data entry. Payments to the optometrists have ensured that all participants attend a training session before joining the programme and attend annually for further education and audit.

In the present study, the sensitivity and specificity of optometrist-generated reports compares well with published data. In a recent review, Bachmannn and Nelson reported that overall sensitivity of screening tests in diagnosing 'referable' or 'sight-threatening' retinopathy with either stereoscopic photography or ophthalmologist ophthalmoscopy as a reference standard was 62 % (95 % CI 49–74).[5] In assessing the amount of agreement between graders of retinal photographs, kappa values have varied between 0.56 and 0.81, and for the diagnosis of retinopathy by ophthalmoscopy between 0.29 and 0.66 for ophthalmologists and 0.32 to 0.72 for general practitioners.[6–8]

For patients with sight-threatening retinopathy, treatment requires input from ophthalmologists, the diabetes team and primary care. Communication between these groups is often inadequate. Furthermore, due to the complexity of the retinal appearances, many patients have long-term ophthalmology follow-up which occupies valuable clinic time, without necessarily having input about diabetes and other risk factors. In Bournemouth, such patients with retinopathy are recalled to a nurse-run Image Clinic where retinal images are taken using computer-based digital technology. The images together with recent measurements of HbA_{1c}, lipids and blood pressure are reviewed by a consultant ophthalmologist and diabetologist and a decision made about further treatment and follow-up. All results and information together with an action plan are sent to the general practitioner and patient. Without the intermediate step of digital imaging, patients with established retinopathy run the risk of indeterminate follow-up within an already overburdened ophthalmology department or will be recurrently recalled to hospital because of abnormal primary screening results. A portable diode laser enables maculopathy treatment and limited retinal ablations to be performed in this clinic, with more extensive retinal ablations undertaken in separate laser clinics. Subsequent follow-up can take place within the Joint Retinal Clinic and/or Image Clinic, with patients alternating between both.

Our analysis suggests that digital images are at least as good as optometrists for initial screening and as 35 mm slides for monitoring progression of retinopathy or

Table 2. Comparisons of optometrist codes, 35 mm photographs and digital images

Optometrist vs 35 mm photographs

		35 mm photographs	
Optometrist codes	STR	NSTR	Total
STR	60	36	96
NSTR	27	194	223
Total	87	230	317
Test sensitivity	0.69	Test specificity	0.84
Positive predictive value	0.63	Negative predictive value	0.87
Kappa	0.62		

Digital images vs 35 mm photographs

		35 mm photographs	
Digital images	STR	NSTR	Total
STR	128	6	134
NSTR	10	191	201
Total	138	197	335
Test sensitivity	0.93	Test specificity	0.97
Positive predictive value	0.96	Negative predictive value	0.95
Kappa	0.90		

Table 3. Comparisons of ophthalmologist coded slit lamp examinations (for patients attending the Joint Retinal Clinic) with digital images

		Slit-lamp examination	
Digital images	STR	NSTR	Total
STR	69	14	83
NSTR	8	33	41
Total	77	47	124
Test sensitivity	0.90	Test specificity	0.70
Positive predictive value	0.83	Negative predictive value	0.81
Kappa	0.61		

Table 4. Details of individual images where the digital images under-reported the presence of sight-threatening retinopathy

Digital image	35 mm image	Reason
BRAG	BRAG	
II	VI	Disc new vessels – poor resolution on digital image
II	VI	Disc new vessels – poor resolution on digital image
I	IV	1 cws[a] without background changes
II	IV	Lens opacity – poor quality images
II	VI	BRVO – coded as ischaemia in 35 mm but not digital image
II	VI	BRVO – coded as ischaemia in 35 mm but not digital image
II	IV	1 cws[a] at periphery
II	III	Minute speculate exudates in macular area
II	III	Minute speculate exudates in macular area
II	III	Poor resolution of macular area on digital image

[a]Cotton wool spot.

response to treatment. Recently, George *et al.*, using similar clinical groups compared digitized images with their original 35 mm colour transparencies and reported a 95 % level of agreement for detecthing sight-threatening retinopathy.[9] In their study 4.5 % of images were undergraded following digitization. Here, problems with resolution resulted in under-reporting of two cases of disc new vessels and one case of maculopathy with digital imaging. It is anticipated that the introduction of cameras with higher resolution (e.g. Canon CR5 45NM with 785×576 pixels) will improve detection. Storage of these images, for example in an electronic clinical record, will allow for prospective assessment of the natural history of all types of retinopathy as well as providing information on the outcome following active treatment. In addition, the production of hard-copy digital images could facilitate the education process by providing feedback to general practitioners and high street optometrists.

As well as providing a permanent and readily accesible record of retinal appearances, digital images have the potential to be processed by autonomic analysis systems. Early work suggests that neutral networks can detect diabetic features in fundus images with a sensitivity

value of 88 % and specificity of 84 % when compared with ophthalmologists.[10] Locally, we have examined a statistical approach to automatic analysis to locate and distinguish specific abnormal appearances (cotton wool spots, exudates, haemorrhages and microaneurysms) by extraction and feeding into a statistical (mahalanobis) classifier.[11]

In conclusion, the combination of primary screening for retinopathy by high street optometrists and digital imaging technology for patients with established retinopathy provides an integrated system for the management of ever-increasing numbers of patients with diabetes mellitus. The use of digital images is particularly time efficient for the ophthalmologist and diabetologist, since assessment of images takes only about two minutes per patient. Digital images provide an efficient method for follow-up of patients with established or previously treated retinopathy, where the appearances can be difficult to interpret, particularly with regard to the need for laser treatment. The use of higher resolution camers and development of automated assessment systems should improve the efficiency and effectiveness of the management of patients with diabetic retinopathy.

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Appendix 1. Basic Specifications of the Digital Imaging System

Computer	486 DX 266–400 Mbyte hard drive
Monitor	17inch large screen SVGA
Operating system	DOS 6.0
Image format	640 X 480, 8 bit grey scale or 24 bit colour
File format	TIFf 6.0
Networking	Novell and Lantastic compatible